DISTRIBUTION OF GLOBAL RADIATION IN WISCONSIN DECEMBER 1966 THROUGH JUNE 1967

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ABSTRACT

Data are presented from a mesoscale network of integrating pyranometers established in Wisconsin, for the period December 1966 through June 1967. The data have been normalized so that they are expressed as a percent of the clear day global radiation values. The monthly values for the percent of the clear day global radiation received over the State, ranged from 72.3 to 58.4 percent. For the 7 months examined, the gradients across the State ranged from 5.5 to 12.8 percent of the possible global radiation. Maps of the monthly distribution patterns have been presented. These have been interpreted in the light of the prevailing weather systems.

1. INTRODUCTION

It is clear that changes in both local atmospheric conditions and the time of year will cause the global radiation measured at any given locality to vary considerably. Although the ESSA Weather Bureau operates a network of Eppley pyranometers which extensively covers the United States, there are few data available which would enable the geographical distribution of global radiation to be examined on a mesoscale basis. The seasonal and synoptic variations across Wisconsin, modified by the proximity to the Great Lakes, and the moderate range in terrain, elevation, and roughness, makes the State an excellent area for examining these mesoscale variations. A statewide pyranometer network was established in Wisconsin during the fall of 1966. Data from this network are presented here for the period December 1966 through June 1967; and the monthly distribution patterns are discussed in relation to the prevailing weather systems and their associated cloud patterns.

2. PYRANOMETER NETWORK

An integrating pyranometer, which comprises a silicon solar cell pyranometer with output recorded by a transistorized current integrator (Kerr et al. [1]), was installed at each of 16 sites in Wisconsin. The sites are listed in table 1 and their geographical locations are shown in figure 1. The network was built around the University of Wisconsin Experimental Farms, the ESSA Weather Bureau first-order airport stations, and the Bureau's cooperating observers. The pyranometers were read each day by the observer. Further details on the network are given by Kerr et al. [2].

3. NORMALIZATION OF THE DATA

There are several advantages to be gained by normalizing the data before they are analyzed. Therefore data were expressed as a percentage of the clear day global radiation value at the given sampling site on the day of measurement. The normalization procedure allows the short-term variations about the mean to be studied as a function of time while eliminating the effect of the long-term time dependency of the mean itself. Normalization of the data also eliminates the pyranometer as a potential source of error when comparisons are made between sites. Both the effects of latitude and of clear day variations in the atmospheric concentrations of aerosols and precipitable water

TABLE 1.—*Location of pyranometer sites in Wisconsin and St. Paul, Minn.*

Site no.	Station	Lat. (° ′)	Long. (° ′)	Elev. (meters)	Description
1	Ashland	46 34	90 58	198	U.W. Expt. Farm
2	Brule Island	45 57	88 13	381	Wis.-Mich. Power Co.
3	Spooner	45 49	91 53	336	U.W. Expt. Farm
4	St. Paul, Minn	44 53	93 13	254	U. of Minn.
5	Wisota	44 56	91 23	256	Northern State Power Co.
6	Antigo	45 08	89 09	442	Sewage Plant
7	Sturgeon Bay	44 52	87 20	200	U.W. Expt. Farm
8	Marshfield	44 39	90 08	381	U.W. Expt. Farm
9	La Crosse	43 52	91 15	199	Weather Bureau
10	Hancock	44 07	89 32	328	U.W. Expt. Farm
11	Two Rivers	44 09	87 34	183	Sewage Plant
13	Lancaster	42 52	90 42	329	U.W. Expt. Farm
14	U.W., Madison	43 08	89 20	262	U.W. Soils Dept.
15	Truax, Madison	43 08	89 20	262	Weather Bureau
16	Milwaukee	42 57	87 54	205	Weather Bureau
17	Monroe	42 36	89 40	305	Sewage Plant

are eliminated. Therefore, the variability in the normalized data is primarily due to the effects of the changing patterns of cloudiness, and secondarily to the changes in the atmospheric concentrations of aerosols and precipitable water which occur on cloudy days. The method of normalizing the data is discussed by Kerr et al. [3].

For convenience the term "percent-radiation" will be used to refer to all data which have been normalized, e.g. 75 percent-radiation means that 75 percent of the clear day global radiation for the given day was received at that particular site.

4. MAPS OF PERCENT-RADIATION

Maps have been prepared showing the isolines of percent-radiation for the months of December 1966 through June 1967. The monthly mean daily percent-radiation was computed for each site. A State mean and its standard deviation was then computed from the 16 site means. An isoline equal to the State mean was drawn on each map, and then additional isolines were drawn at intervals of 0.5 standard deviation units on either side of the mean line.

The State mean daily percent-radiation varied considerably from month to month. The February (71.3) and May (72.0) means of daily percent-radiation were significantly higher than the December (59.3) and April (58.4) means. The June (62.2), January (63.6), and March (67.0) means were intermediate.

The monthly maps of percent-radiation are now discussed in terms of the prevailing weather patterns.

DECEMBER 1966

Figure 1 shows that there were few distinctive features about the December weather which affected the distribution of percent-radiation. Percent of possible sunshine reported from the first-order Weather Bureau stations for the month was 6–8 percent higher than the long-term average of approximately 40 percent. The lowest values of percent-radiation were reported at Brule Island (Site 2). Frequent snow flurry activity was reported from this station. Cold Arctic air masses moving across Lake Superior move from the cold land surface onto the warmer lake surface and this produces instability resulting in heavy precipitation on the south shore of the Lake and over the highlands along the Wisconsin-Michigan border. The relatively low frequency of easterly winds gave Lake Michigan shore areas more sunshine than usual for December.

JANUARY 1967

Low percent-radiation values are shown in figure 2 along the Lake Michigan shoreline and at La Crosse (Site 9). Precipitation varied from normal in the south to about three times normal in the north and west. Unusually low radiation totals recorded at La Crosse on several days in early January coincided with heavy fog and frequent snow at that station. Calm and clear winter days with light westerly winds blowing off the cold land surface onto the warmer Lake Michigan gave rise to instability, and a cloudbank forms over the Lake. This cloudbank can have very local effects in covering the morning sun and could be of more significance at the lakeshore location at Two Rivers (Site 11) than at Milwaukee (Site 16) which is several miles inland. Days

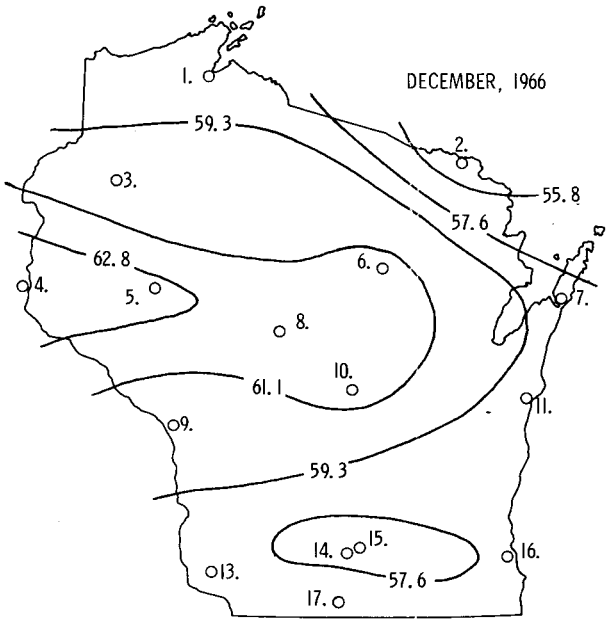

FIGURE 1.—The average daily percent-radiation for December 1966. (Mean=59.3±3.5) The numbered circles indicate locations of pyranometer sites listed in table 1.

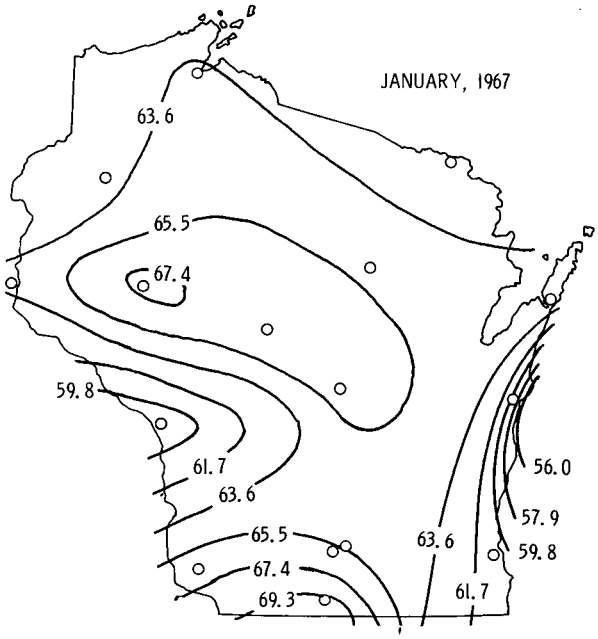

FIGURE 2.—The average daily percent-radiation for January 1967. (Mean=63.6±3.8)

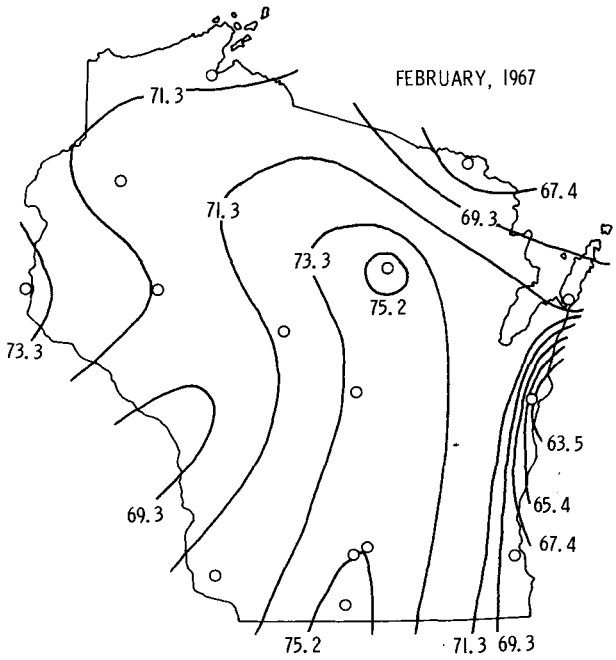

FIGURE 3.—The average daily percent-radiation for February 1967. (Mean=71.3±3.9)

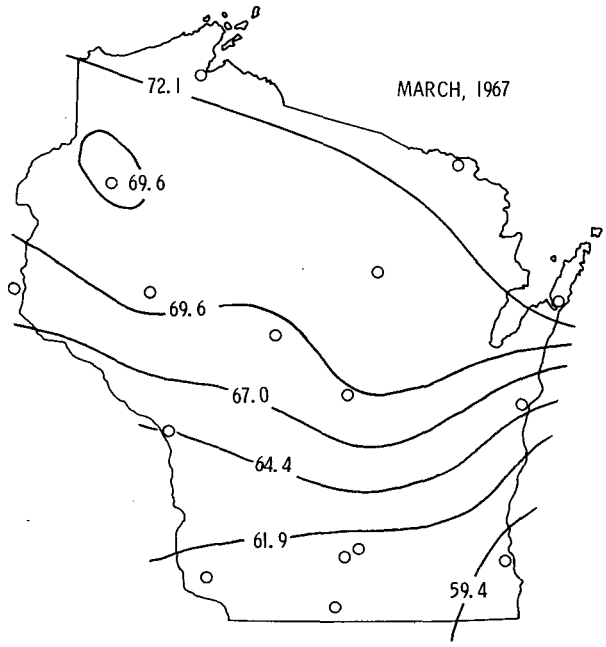

FIGURE 4.—The average daily percent-radiation for March 1967. (Mean=67.0±5.1)

with easterly winds also result in more cloudiness over the counties bordering Lake Michigan. A frequency of 6 days with resultant winds between the north and east at Green Bay (first-order Weather Bureau station about 30 mi. northeast of Two Rivers) compared to only 3 days at Milwaukee may partly explain the lower radiation values at Two Rivers. The tongue of low percent-radiation from La Crosse to Two Rivers coincides with the track of several cyclones across the State and with the cloudiness resulting from overrunning north of the associated frontal zones.

FEBRUARY 1967

February was mostly fair and cold with precipitation and cloudiness patterns typical of a winter month with strong northwesterly flow aloft. Considerable sunshine was recorded, interspersed with frequent light and brief snow flurry type of precipitation. Percent of possible sunshine reported from the first-order stations was above the long-term average of 45–55 percent. The southern lakeshore counties were again unusually sunny relative to areas farther north (fig. 3). This is shown by the fact that Milwaukee had 56 percent of possible sunshine compared with the normal 44 percent, whereas Green Bay recorded 51 percent versus the normal 50 percent of possible sunshine. The frequency of the northeasterly winds off Lake Michigan and the persistent cloudiness and snow flurries again increased moderately north of Milwaukee. The Brule Island site in the extreme northeast was affected by Lake Superior cloudiness and snow flurries similar to December.

MARCH 1967

Weather up to March 20 was unusually settled and cool with the majority of the storm tracks crossing the Continent south and east of the State. The cloud shields and light precipitation associated with the overrunning phenomenon north of the frontal zones did affect the southern and southeastern areas causing a strong radiation gradient across the State with high values in northern areas and relatively lower values in the south (fig. 4). Milder weather with scattered showers throughout the State late in the month did not affect the percent-radiation gradient.

APRIL 1967

April was unusually cloudy as determined from both the percent of possible sunshine and percent-radiation averages for the month. Green Bay (36 percent) had a relatively lower percent of possible sunshine than Madison (43 percent) which is in contrast to the percent-radiation values given in figure 5. This discrepancy may be explained by the fact that even though these two stations lie roughly along the same track underneath the upper steering current of high clouds and precipitation, Green Bay experienced very little precipitation during the hours 9:00 a.m. and 3:00 p.m. while Madison 100 mi. upwind experienced more frequent precipitation during these high radiation hours. The time of day at which the sun is shaded will have an important bearing on the pyranometer but will have little effect on the sunshine recorder. The cold Great Lakes dampen convective activity during spring and summer. The resulting lower cloudiness in the shoreline area had begun to influence the percent-radiation pattern in April.

MAY 1967

During the first 2 weeks of May, when northwest flow aloft prevailed across the region, several Lows moved southeastward across the northern part of the State in a

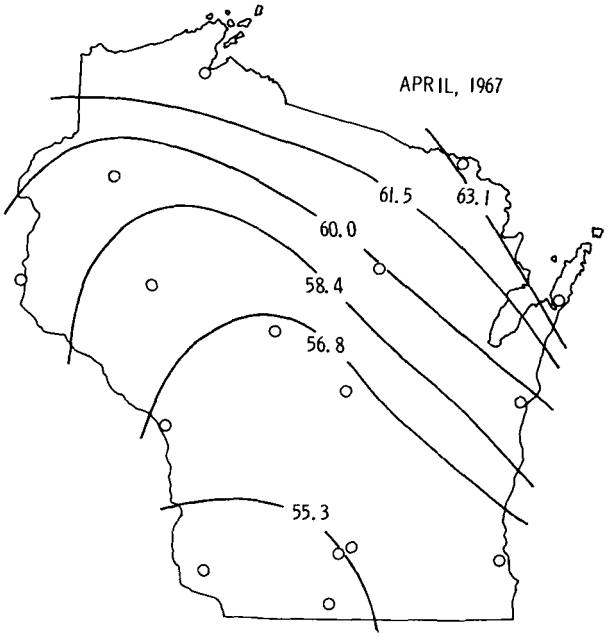

FIGURE 5.—The average daily percent-radiation for April 1967. (Mean=58.4±3.1)

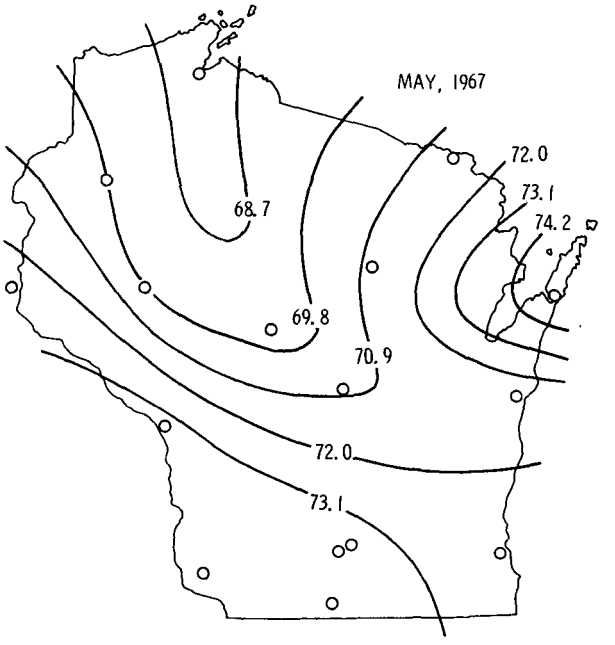

FIGURE 6.—The average daily percent-radiation for May 1967. (Mean=72.0±2.2)

pattern more typical of midsummer. The effect of these systems was to reduce the percent-radiation in the north of the State as shown in figure 6, but skies in the south were relatively clear when these systems passed through. The Lows apparently passed to the south of the Sturgeon Bay station (Site 7) which recorded high percent-radiation values. During the final days of May the strong blocking of a High to the north gave the whole State clear skies. The State mean daily percent-radiation was 93.6 on May 31.

JUNE 1967

The distribution of percent-radiation shown in figure 7 reflects the weather patterns of June. High global radiation and dry easterly winds were recorded throughout the State for the first few days of the month. On June 5 a front became stationary along an axis roughly from La Crosse to about Brule Island. The front did not move far from this proximity until June 16. Considerable cloudiness and unsettled weather were associated with the front. During this period, when southwest winds generally prevailed over the region, the Lows and waves on the front followed a northeasterly path across the State. The passage of several of these Lows was timed so that the showers fell at night in the La Crosse area but during daytime farther to the northeast. Consequently, there was a gradient of decreasing percent-radiation in a northeasterly direction from La Crosse. Westerly winds dominated the weather patterns after June 18.

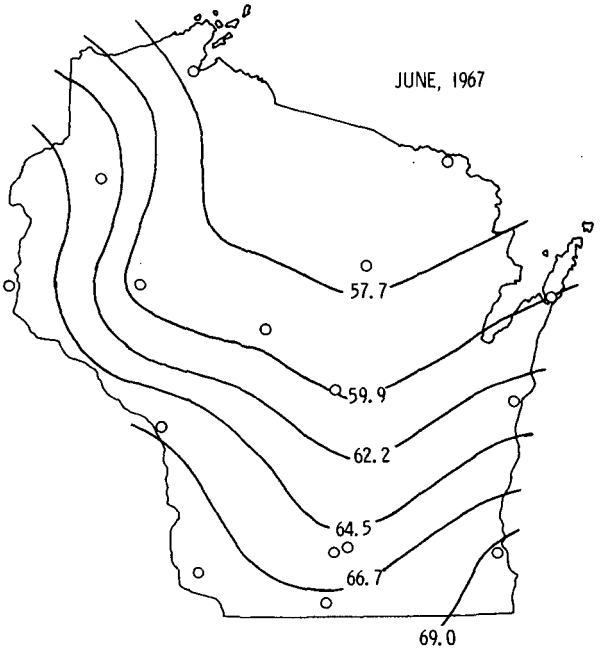

FIGURE 7.—The average daily percent-radiation for June 1967. (Mean=62.2±4.5)

5. CONCLUSIONS

Maps showing the geographical distribution of percent-radiation were drawn from the normalized data. Distinct patterns were evident on the maps which could be interpreted in terms of the prevailing weather systems. Gradients across the State ranged from 5.5 to 12.8 percent of the possible global radiation for the month. Variations in global radiation of this order of magnitude can be of considerable significance in the processes with which we are concerned in agriculture, hydrology, and meteorology.

The relationship of the land surface temperatures to the water surface temperatures of the Great Lakes has an important influence on the cloud and weather systems

which develop in the vicinity of the Lakes and will therefore exercise a seasonal effect on the percent-radiation in this region.

The scale of the present network is not sufficiently small to determine many of the local variations in global radiation. This network cannot isolate small-scale variations due to local terrain features, small lakes, cities, changes in soil types and vegetation covers, and small sources of atmospheric pollution, but it clearly shows a considerable variability in global radiation across the State that cannot be determined if only one or two measurements are made in an area of this size.

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